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Bacteriological and Physicochemical Characterization of Water from Wells in Urban areas of the District of Maroua III (Far North Cameroon).

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Abstract - In the 3rd district of Maroua, the extension of neighborhoods is not accompanied by the extension of the network of Cameroonian Water Company (CWC) or by building protected well;people are forced to consume well water. Consumption of this water of dubious quality and the exposedthem to waterborne diseases. Characterization of well water would be very important to establish the potential health risks and establish a management system that would ensure the supply of quality water. The results of this investigation show the presence of suspended solids (0.0355 ± 0.0261 mg / L) in all water samples, the values of phosphates are high (0.51 ± 0.16 mg / L) in P_2 wells (0.727 mg / L) P_4 (0.815 mg / L) and P_9 (0.55 mg / L). The electrical conductivity is also high in the samples wells P_3 (1442 ± 12 µs / cm), P_8 (1988 ± 9 µs / cm) and P_{10} (1061 ± 6 µs / cm). The presence of faecal coliforms (8.40 ± 8.40 x 10^4 CFU / 100 mL) and faecal streptococci (1.515 ± 3.723 x 10^8 CFU / 100 mL) in high proportions in all samples requires animal faecal pollution. This investigation shows that all the water samples contain high amounts of bacteria and therefore the water from these wells is not safe to drink without it has undergone a prior treatment.

Keywords – faecal coliforms, faecal streptococci, suspended solid, wells.

Introduction

The area of the Far North of Cameroon is characterized by low annual rainfall. The average rainfall decreased from 700mm to 500mm before 1970 in recent years.The average temperature is 30°C with high daily and annual amplitudes [1]. Access to water quantity and quality in the city of Maroua is a major problem for people. The main sources of drinking water are the connection to the network of the Cameroonian Water Company(CWC), boreholes constructed by non-governmental organizations and government. In the 3rd district of Maroua which has an area of 2980 km^2 with an estimated 86,574 inhabitants, 43,714 men and 42,860 women [2], access to public drinking water is becoming increasingly difficult with the advent of the University of Maroua which caused an increase in population. This increase in population has resulted in the immediate extension of the city and the proliferation of human activities generating wastes that are causing pollution of groundwater [3]. The use of the population to well water due to low water availability from the network of the CWC and protected wells.

The use of water in food processes (drinking, cooking, distillation traditional beer "the bilbil" dishes, etc.) is a health risk to consumers [4]. Cholera is thus a public health problem in the Far North of Cameroon. From 1996 to 2010, the region has experienced several outbreaks both in the rainy season than in the dry season [2]. In 2010, this region has recorded more than 9,000 cases detected for more than 600 deaths[5-6]. According to statistics from the Regional Delegation of Public Health of the Far North, in the urban district health Maroua, was recorded in 2013, 05 cases of cholera, 481 cases of bloody diarrhea, 543 cases of gastroenteritis and 940 cases of typhoid. Microbiological pollution is characterized by the search for bacterial germs witnesses faecal contamination considered bios indicators such as total coliforms, faecal coliforms, heterotrophic aerobic mesophilic bacteria and faecal streptococci. Contamination of water is the source of outbreaks [7-8].

The development of microbial communities in surface waters, as well as in groundwater is related to meteorological factors and all the physico-chemical and biological characteristics of the biotope[9-10].

The aim of this study is to identify wells near sources of wastewater generation to highlight the mineral and bacterial pollution of water in ten wells located in neighborhoods extension and to determine some physicochemical and biological characteristics of the water consumed by people in neighborhoods in the borough extension Maroua third wells. More specifically, it focuses on the assessment of key physicochemical

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factors responsible for the variation in the overall quality of these waters and the search controls germs of faecal contamination. This is done from the assumption that: the physicochemical and bacteriological quality of the water depends on the distance between the wells and privies activities around the book.

2. Materials and methods

2.1.Apparatus

These analyzes were performed using a spectrophotometer UV-VIS spectro brand RS UV-2500 spectrophotometer to assay nitrate ions (500 nm), phosphate ions (890 nm), ammonium ions (425 nm) and suspended solids (810 nm); a liquid column thermometer graduated in 10thdegres and the reading after ten minutes of immersion temperature; a multi-parameter brand "EXTECH" to measure the electrical conductivity and total dissolved solids (TDS); a pH meter mark International Wagtech to measure the pH of the water.We used a GPS MAP 62 Garmin. Electrical conductivity, temperature and pH were measured on site at the time of sampling and the other on the same day in the laboratory.

2.2.Sampling and study site

Maroua is located at 10 ° 35 'north latitude and 14 ° 19' east longitude[11]. The climate is Sudano-Sahelian characterized by a dry season that lasts seven months and a rainy season from five months [1]. The drainage system consists mainly of seasonal streams (the Mayos).

Ten water wells rated P_1; P_2; P_3; P_4; P_5; P_6; P_7; P_8; P_9 and P_{10} were sampled in the neighborhoods of the borough ofMaroua third (fig 1), depending on the persistence of the productivity of the work, the use of water by people in the process of consumption and the proximity of the wells with production sources of wastewater that are latrines, farms, garbage deposits (table 1) etc. These wells were sampled in April 2014 (dry season) and to July 2014 (the beginning of the rainy season).

Samples of 310 mL of water to each sample per well and were transported to the laboratory in sterile glass bottles kept cold with ice in a refrigerated cooler and analyzed the same day.

Table 1: characteristics of the sampled wells

well	GPS location (altitude)	neighbor hoods	potential source of pollution	Protection of the well	Water Use	Healthwell
P_1	N10.61644 E014.33999 (398 m)	DOUGGOI SARARE	Latrine within 20m, small agriculture around, the cattle stayed there near	No protection against the elements	Drink, mealpreparation	Disinfected with bleach once a year
P_2	N10.61924 E014.33860 (399 m)	DOUGGOI SARARE	Agricultural activity all around with fertilizer use	Not covered against rain and sun	water used for drinking and household chores	Cleaned and disinfected with bleach every six months
P_3	N10.61160 E014.34358 (401 m)	LOUGGEO	Located 6 m of a ravine draining wastewater The cattle stayed there near	No protection against the elements	Drink, mealpreparation	Never drained or disinfected
P_4	N10.61561 E014.34682 (390 m)	LOUGGEO	After grazing, the animals stay within 5m and defecate there next	No cover to protect against water weather	water used for drinking and household chores	Cleaned and disinfected with bleach every six months
P_5	N10.61626 E014.34523 (392 m)	LOUGGEO	Agricultural activity around a large area with fertilizer use	Buses dirt in clothes and dishes are washed defection	Used in the process of consumption by people	drained and disinfected with bleach every six months
P_6	N10.62352 E014.36847 (385 m)	DJARENGOL KODEK	Located under the trees The cattle stayed there near	Well crank down turned into open wells	The water is used by people for drinking and preparing food	Never cleaned or disinfected
P_7	N10.62273 E014.37584 (386 m)	DJARENGOL KODEK	Agricultural activity around the well with the use of cow dung	Weathered	Consumption and mealpreparation	Drained once ayear
P_8	N10.61172 E014.33746 (390 m)	BIKORDI	Latrines within 10 m	Treewithin 10 m	Water used for consumption	Cleaned, drained and disinfected once every six months
P_9	N10.62660 E014.36937 (389 m)	DJARENGOL KODEK	Located near a field under trees	Volanta down with a lid	Water used in the process of consumption	Cleaned and disinfected with bleach every three months
P_{10}	N10.61179 E014.33899 (386 m)	BIKORDI	Located less than 15 m from latrines	Open within 5 m of a tree	Used for drinking and cooking	neverdisinfected

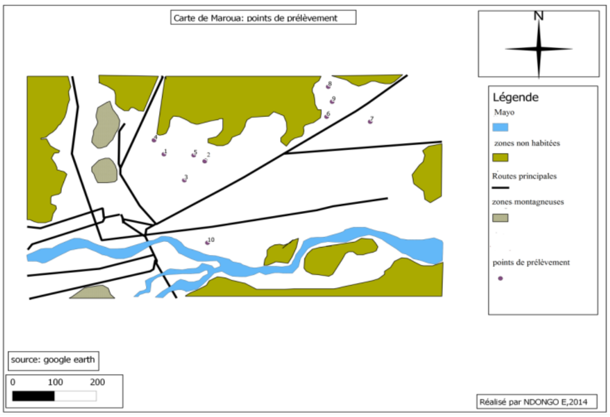

Figure 1: location map of wells in the study area

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3. Results and Discussion

3.1. Bacteriological analysis

These analyzes were carried on the detection of total coliform (TC), faecal coliforms (FC), fecal streptococci (FS) and heterotrophic aerobic mesophilic bacteria (Hamb) using a combination of methods dictated by Rodier[12] of those with American Public Health Association (1998).

Counting is performed by seeding Hamb surface of nutrient agar Agar on tryptone yeast extract glucose single layer after incubation at 37 ° C for 24 hours. FC counting is performed by seeding the surface of the agar AGARTryptone lactose single layer after incubation at 44 ° C for 24 hours. Counting TC is performed by seeding the surface of the agar AGARtryptonelactose single layer after incubation at 37 ° C for 24 hours.The FS count is done on the beef peptone agar Agar incubated at 37 ° C for 48 hours.

Dilutions were performed with a sodium chloride solution (8.5g NaClin 1000 mL of distilled water) sterilized at 121°C for 15 minutes. A petri dish containing the culture medium for each dilution (10^{-2} to 10^{-3}) are inoculated and incubated at a temperature compatible with the multiplication of each type of bacteria.

The results are expressed as colony forming units per 100 mL (CFU / 100 mL).

Table 2: Classification according to faecal pollution and Borrego Romero

N°	FC/FS	Source of Pollution	Observations
1	>4	Essentiallyhuman pollution	Wastewaterdischarge
2	2< FC/FS<4	Mixed pollution to human dominance	/
3	1< FC/FS<2	Uncertain pollution	/
4	0,7<FC/FS<1	Mixed animal pollution predominance	/
5	<0,7	Animal pollution, includinglivestock	Particularlysheep

The high temperature values in water samples with a mean value of 27.8 ± 0.2 ° C reflect the ambient temperature during the study period. The temperature which is above the indicator value of pollution which is 25 ° C for Rodier, may favor the growth of some bacteria or cause the death of others. In this case, the result shows a significant microbial load in all samples. Therefore, this temperature would have supported a significant increase in TC, FC, FS and Hamb.

Although not vary significantly, the pH are different from one well to another. According to Close et al [13],this difference is due to the nature of the soil and human activities around the well. The values of these will be around pH 7.70 ± 0.09. They therefore belong in the range of pH values indicative of a drinking water [14](6.5 to 8.5 according to WHO, 1996).

The high amount of bacteria in water samples could be explained by the practice of agriculture and / or livestock around the well, a lack of protection and development of structures, proximity to latrines, trees and non-compliance with hygiene by people. The high values of Hamb2.62 ± 6.88 x 107 CFU / 100 mL), FS (1.51 ± 3.72 x 106 CFU / 100 mL) and TC (9.575 ± 1.9 x 106 CFU / 100 mL) could be explained by the presence of suspended solids in these waters. The correlation is statistically significant and strong between total coliform (TC) and total suspended solids (TSS) ($r = 0.742$; $p <0.05$); the Hamband TSS ($r = 0.757$; $p <0.05$); FS and SS ($r = 0.763$; $p <0.05$). Thus, the amount of bacteria found in water would be proportional to the concentration of suspended solids. Suspended solids would be a good source of carbon that would allow them to grow on a large scale.

3.2.Physicochemical analysis

The values of electrical conductivity have to average 874.30 ± 509.878 S / cm. Except wells P_3 (1442 ± 12 S / cm), P_8 (1988 ± 9 S / cm) and P_{10} (1061 ± 6 S / cm) which have values that are above the standard, the values of other wells are relatively lower than the WHO standard of 2002 (1000 S / cm). The high values are due to waste water from the ravine located less than 7 m from P_3 to P_{10} proximity to latrines or rejection of organic matter (dead leaves falling from tree branches located above the well or other types of organic materials from the periphery) to the wells. These materials are well mineralization due to microorganisms contained in the water and cause the elevation of the amount of mineral dissolved in the water and consequently the increase in the electrical conductivity.

Nitrate concentrations are below the WHO recommended (50 mg / L) for drinking water value. These values (0.22 ± 0.15 mg / L) are lower than those obtained byMbawalaat Dang in 2010 [15]. However, as explained, these concentrations can encourage the development of nitrifying bacteria. These nitrates come from fertilizers or animal and human excreta.

The ammonium content of the water (0.1125 ± 0.1288 mg / L) is less than the limit value indicator WHO pollution (1.5 mg / L). The presence of ammonium is due to human activities (garbage and sewage of domestic origin) or degradation of organic matter found in the well.

The concentration of phosphates in water is greater than some value indicative of the pollution of the WHO (0.5 mg / L). This is due to human activities (laundry and dishes around the well); fertilizer used in areas where agriculture or contamination by excreta beef is practiced.

Concentrations of suspended solids (0.0355 mg / L ± 0.0261) are lower [15].According to the guidelines of the Council of the European Communities, they should be absent in drinking water. They indicate the pollution

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caused by the discharge of waste into the well (using dirty containers to collect water).

The concentrations of total dissolved solids (TDS) that are greater than the standard of drinking water in WHO (2000) is 1000 mg / L would be due to the phenomena of mineralization of organic matter by microorganisms present in the water [5].

3.3. Statistical Analysis

Statistical analyzes were performed using SPSS version 2.0 and version 6.7 software Stat Box. The origin of faecal pollution was determined using the method of Borrego and Romero (1982), which allows determining whether faecal pollution of human or animal origin mixed.

Table 3 : statistical values of various physicochemical parameters studied.

Wells	PH	Temperature (°C)	EC (µS/cm)	NH_4^+ (mg/L)	NO_3^- (mg/L)	TDS (mg/L)	PO_4^{3-} (mg/L)	MES (mg/L)
P1	7,75±0,113	28 ±0,15	323 ± 5	0,088±0,1	0,04±0,09	219±13	0,41±0,08	0,091 ±0,01
P2	7,73±0,072	28 ±0,14	675 ±3	0,069±0,09	0,096±0,08	478±11	0,727±0,05	0,037 ±0,02
P3	7,74±0,063	28,1 ±0,21	1442 ±12	0,027±0,12	0,174±0,13	1041±9	0,405±0,07	0,017 ±0,03
P4	7,71±0,099	27,8 ±0,19	795 ± 11	0,018±0,15	0,309±0,06	560±14	0,815±0,03	0,025 ±0,01
P5	7,64±0,089	27,8 ±0,22	741 ±7	0,253±0,06	0,501±0,14	518±18	0,49±0,05	0,046 ±0,01
P6	7,65±0,098	27,7 ±0,23	772 ±5	0,416±0,08	0,185±0,17	545±6	0,54±0,06	0,012 ±0,02
P7	7,47±0,112	27,6 ±0,12	618 ±6	0,012±0,013	0,195±0,08	436±12	0,49±0,02	0,063 ±0,01
P8	7,77±0,115	27,6 ±0,11	1988 ± 9	0,097±0,15	0,335±0,15	1395±11	0,37±0,02	0,022 ±0,012
P9	7,75±0,10	27,7 ±0,20	328 ±7	0,124±0,17	0,053±0,09	228±7	0,55±0,03	0,004 ±0,016
P10	7,83±0,113	27,7 ±0,15	1061 ±6	0,021±0,07	0,362±0,12	742±9	0,275±0,04	0,038 ±0,01

Table 4 :statistical values of the various parameters studied bacteriological.

Wells	TC	Hamb	FS	FC	FC/FS
P1	6,5 x 10^7 ±1,1	2,22 x 10^9±2	1,21 x 10^9±3	1,5 x 10^5±1,3	0,00012397
P2	8 x 10^6 ±0,9	6,87 x 10^7 ±2,1	4,14 x 10^7±1,5	1,07 x 10^5±1,1	0,00258454
P3	1,65 x 10^6 ±0,7	2,15 x 10^7±1,3	5,12 x 10^7±3,2	2,36 x 10^4±2	0,00046094
P4	1 x 10^6 ±1,3	7,76 x 10^7±2,4	5,66 x 10^7±2	2,83 x 10^5±2,2	0,005
P5	6 x 10^6 ±1,4	9,6 x 10^7±3,1	5,86 x 10^7±7,1	7,96 x 10^4±3,2	0,00135836
P6	2 x 10^5 ±1,5	1,16 x 10^7±2,2	9 x 10^6±1,2	2,24 x 10^4±2,1	0,00248889
P7	6 x 10^5 ±0,6	3,48 x 10^7±2,1	4,22 x 10^7±2,4	3,96 x 10^4±2,2	0,00093839
P8	3,9 x 10^6 ±1,3	7,52 x 10^7±3	2,59 x 10^7±3,4	2,14 x 10^4±2,4	0,00082625
P9	5,9 x 10^6 ±0,4	8,9 x 10^6±2,8	5,6 x 10^7±1,6	1,03 x 10^5±2,1	0,01839286
P10	3,5 x 10^6 ±0,8	4,6 x 10^6±2,7	1,52 x 10^7±1,1	1,12 x 10^4±3	0,00073684

Tables 3 and 4 above indicate the values of the different physicochemical parameters and their minimum and maximum values, as well as means and standard FC /FS ratios in all wells deviations.

It is apparent from these tables that the measured temperatures are from 27.6 ° C minimum (P_7 and P_8 wells) 28.1 ° C maximum (P_3 well) for an average of 27.8 ± 0.2 ° C. The obtained temperature values exceed 25 ° C, maximum value indicative of pollution according Rodier. These wells are therefore exposed to the pollution.

The pH of well water is between a minimum of 7.47 (P_7) and a maximum of 7.83 (P_{10}) for an overall average of 7.70 ± 0.09. Although slightly alkaline, the water of these wells have pH between 6.5 and 8.5 which are indicative of the terminal to WHO water intended for human consumption.

The recorded during our study electrical conductivity ranges from 323 S / cm at well P_1 to 1988 S / cm at P_8 wells for an average of 874.30 ± 509.878. The electrical conductivity of the well P_8 (1988 S / cm) is well above the norm.

Well water are analyzed nitrate ranging from 0.04 mg / L (P_1 well) and 0.501 mg / L (P_5 well) and are below the WHO recommended value. These low values of nitrates, despite the proximity of the wells with the potential sources of pollution (latrines) and by the Centre of Expertise in environmental analysis of Quebec (2004) are due to the phenomenon of self-purification of the soil.

The analysis of the ammonium content shows little variation between 0.012 mg / L (P_7) minimum and 0.416 mg / L (P_6) which are up less than 1.5 mg / L limit recommended by WHO. To the Centre of Expertise in environmental analysis of Quebec, this is explained by the fact that the ammonium is absorbed on the particles of soil and clay.

A variation of the observed phosphate concentration between 0.275 mg / L (P_{10}) and 0.815 mg / L (P_4). Higher values P_2 (0.727 mg / L) P_4 (0.815 mg / L), P_6 (0.541 mg / L) and P_9 (0.55 mg / L) which are above the indicator value of 0.5 mg pollution / L [11].These values indicative of pollution are due to fertilizers used in areas where agriculture is practiced (well P_2, P_6 and P_9) or well contamination by excreta of beef.

The lower value of the concentrations of suspended solids in the samples studied is that of the well P_9 which is 0.004 mg / L and greater than the well P_1qui is 0.091 mg / L. The average values of 0.0355 mg / L ± 0.0261. These results are contrary to the directives of the European Community Council who would like suspended solids are absent in water intended for human consumption. The presence of suspended solids is due to the rains return, the particles suspended in the air (not covered well) or discharges of organic matter in the book.

The total dissolved solids (TDS) vary between a minimum of 219 mg / L (P_1 well) and the maximum 1395 mg / L (wells P_8). No value in this series is higher than

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the WHO standard is 1500 mg / L. However, in wells P_3 and P_8, the amount of total dissolved solids justifies increase in the electrical conductivity.
In all wells, analysis of FC / FS ratio is less than 0.7 and so would faecal pollution and animal including livestock.

Table 5: Contribution of wellfor the nine wells axes

Samples	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
P_1	75,514	10,749	0,501	0,074	1,227	0,031	1,621	0,2	0,081
P_2	0,807	5,337	11,526	1,298	4,89	6,16	1,278	56,156	2,549
P_3	2,565	9,805	12,542	2,918	12,155	24,4	2,258	22,827	0,529
P_4	0,004	17,569	25,207	18,572	11,949	0,842	2,829	4,171	8,856
P_5	0,675	0,762	10,227	2,668	24,679	8,542	22,014	0,919	19,514
P_6	2,542	4,596	13,299	32,252	5,998	3,132	6,54	0,243	21,398
P_7	0,016	4,903	25,871	23,504	32,037	0,395	2,689	0,213	0,371
P_8	14,609	24,372	0,149	1,562	2,833	1,388	32,318	3,028	9,74
P_9	0,014	9,677	0,505	16,483	4,159	31,636	0,033	8,632	18,862
P_{10}	3,254	12,229	0,172	0,669	0,071	23,474	28,42	3,611	18,099

Table 6:contribution of the variables for the nine axes.

Parameters	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
pH	0,009	10,243	23,031	10,345	7,397	23,838	7,304	15,488	2,333
température	4,886	0,848	18,29	4,015	0,986	48,7	19,906	1,999	0,013
CE	9,383	15,727	3,05	1,449	0,555	4,629	14,417	0,414	0,009
NH_4^+	0,326	1,894	15,165	32,349	32,152	7,577	1,675	0,943	2,627
NO_3^-	6,47	0,855	1,92	20,222	36,389	0,603	21,356	0,866	3,809
TDS	9,435	15,505	3,273	1,318	0,378	5,45	13,868	0,102	0,156
PO_4^{3-}	0,18	28,531	10,838	0,863	1,952	4,615	7,35	28,083	2,701
MES	11,543	2,267	7,299	19,545	0,218	2,575	1,733	33,113	10,1
TC	17,819	4,759	0,127	0,231	1,773	0,201	1,502	0,391	65,164
Hamb	17,579	4,71	0,271	0,001	2,333	0	4,288	1,374	1,02
FS	17,741	4,686	0,228	0,002	1,757	0,036	3,429	3,24	7,963
FC	4,629	9,974	16,507	9,661	14,11	1,776	3,172	13,987	4,105

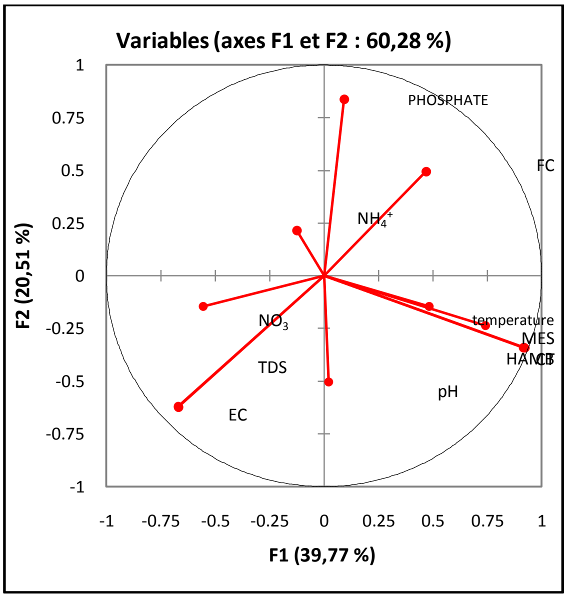

Figure 2: Circle correlation variables

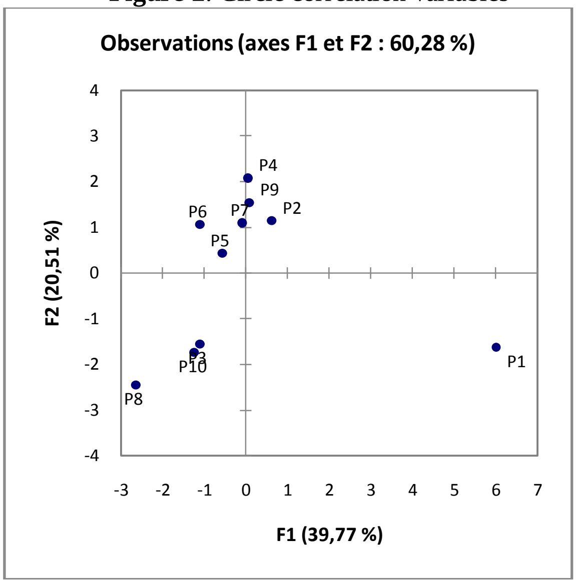

Figure 3: Mapping different wells

To group wells on the basis of physico-chemical and bacteriological analysis, we chose different axes called principal components (P_C) which constitute the fundamental tool of principal component analysis. Performed according to the criteriaof Kaiser[16] among the nine major components generated and each having a "Eigen value" greater than 1, four were retained and can explain 60 28% of the variation between wells. Tables 6 and 7 show the contribution of each mineral on the two main axes. Analyzed each parameter having a value greater than 8.33% is considered representative for this axis.
The principal component 1 (P_{C1}) that expresses represented 39.77% of the variation in the physico-

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chemical and bacteriological parameters MES (11.54%), TC (17.82%), Hamb (17.58%), FS (17.74%) and Mg (9.83%). These parameters on this axis, with positive contributions tend to be the most important parameters because they alone represent more than 74.51% of the variation on this axis.

The P_{C2} axis meanwhile expressed 20.51% and is composed of the following parameters and ranked in descending order according to representativeness: Phosphates (28.53%), EC (15.73%), TDS (15, 50%), pH (10.24%) and FC (9.97%).

The principal component analysis generates data that specify the location of each well in the axis of the main components systems. This mapping allows the observation of similar wells that are characterized by their combination in the figure and those that are different are characterized by their remoteness. Figures 2 and 3 show the position of the wells on the axes and planes P_{C1} P_{C2}.Table 6 shows the contribution of the wells on each axis. Those having more than 8 in each contribution axis plane are considered having a high performance. This allows you to see the wells P_1, P_3, P_4, P_8, P_9 and P_{10} are well represented on the x axis plane P_{C1} P_{C2}. we note that this projection plane, the well P_1 is isolated other and strongly contributes (75.51%) in the construction of the P_{C1} axis. Moreover wells P_3 (9.80%), P_{10} (12.23%) and P_8 (24.40%) in turn contributing to the development of the P_{C2} axis but negatively. Wells P_4 (17.57) and P_9 (9.70%) are characterized by a positive contribution on the principal component P_{C2}.

There was a significant and strong between phosphate content and the number of faecal coliform statistical correlation ($r = 0.738$; $p = 0.015 < 0.05$). The amount of faecal coliform would depend on the phosphates content of the medium. If the phosphates concentration is high, the content will be high faecal coliform vis versa. This would mean that faecal coliforms would have preferred nutrient, phosphates.

There is a strong significant correlation between TC and FS ($r = 0.999$; $p < 0.01$). It is explained by the fact that TC is a group of bacteria used as an indicator of pollution since the 19th century while the presence of FS in water is evidence of faecalpollution. The health risk connected directly to the presence of TC is low with the exception of some opportunistic bacteria that can cause serious illness in debilitated patients. The correlation between these two groups of bacteria is also the result of a division, outside the intestine of humans and animals living environments identical (soil and vegetation)[17].

The strong significant correlation ($r = 0.999$; $p < 0.01$) between the Hamb and TC; Hamb and the FS shows that the strong presence of Hamb is synonymous with a strong presence of TC and FSvisversa.The enumeration of Hamb is to estimate the overall bacterial population in drinking water[18].It allows an overall assessment of the safety of water [19].Given that the vast majority of these bacteria are non-pathogenic, except in individuals with weakened immune system. This result supports the concerns who believe that there would be a relationship between these bacteria and the risk to public health associated with the presence in water of potentially pathogenic bacteria such as faecal streptococci[20].

The correlation analysis between the different parameters was performed using the Pearson correlation test. The results of this analysis are shown in Table 7.

FC / FS reports of ten wells are all less than 0.7 would mean that faecal pollution from livestock including and specifically sheep and oxen, as they defecate near wells. And parasites that are found in their gut migrate and are found in the well (by trickling through direct contact between the bucket with which it draws water and excreta of animals).

The principal component analysis could be used to suggest that the P_1 to a high temperature and is very rich in Hamb, FS and has a high concentration of suspended solids well. Wells P_3, P_8 and P_{10} are very rich in NO_3^-, have a high concentration of TDS and high electrical conductivity. P_4 and P_9 wells are rich in NH_4^+, FC and PO_4^{3-}.

Table 7:values of the coefficient of correlation between physicochemical and biological variables of 10 wells

Parameters		pH	Température	EC	NH_4^+	NO_3^-	TDS	PO_4^{3-}	MES	TC	Hamb	FS	FC
pH	Correlation coefficient (r)	1											
	p												
Temperature	Correlation coefficient (r)	0,299	1										
	p	0,401											
EC	Correlation coefficient (r)	0,298	-0,13	1									
	p	0,403	0,721										
NH_4^+	Correlation coefficient (r)	-0,172	-0,188	-0,141	1								
	p	0,634	0,604	0,697									
NO_3^-	Correlation coefficient (r)	-0,038	-0,366	0,452	0,116	1							
	p	0,917	0,298	0,189	0,75								
TDS	Correlation coefficient (r)	0,294	-0,115	1,00**	-0,144	0,444	1						
	P	0,41	0,752	0	0,691	0,198							

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PO_4^{3-}	Correlation coefficient (r)	-0,245	0,15	-0,39	0,028	-0,179	-0,386	1					
	p	0,495	0,678	0,265	0,938	0,621	0,271						
MES	Correlation coefficient (r)	-0,258	0,2	-0,367	-0,253	-0,089	-0,374	-0,199	1				
	p	0,472	0,579	0,297	0,481	0,807	0,287	0,581					
TC	Correlation coefficient (r)	0,211	0,424	-0,397	-0,072	-0,438	-0,403	-0,196	0,742*	1			
	p	0,558	0,222	0,256	0,843	0,206	0,248	0,587	0,014				
Hamb	Correlation coefficient (r)	0,157	0,402	-0,372	-0,068	-0,413	-0,377	-0,19	0,0757*	0,992**	1		
	p	0,666	0,249	0,29	0,851	0,235	0,282	0,598	0,011	0			
FS	Correlation coefficient (r)	0,147	0,421	-0,375	-0,084	-0,418	-0,38	-0,192	0,0763*	0,990**	0,999**	1	
	p	0,686	0,225	0,285	0,818	0,23	0,278	0,595	0,01	0	0		
FC	Correlation coefficient (r)	0,056	0,245	-0,432	-0,239	-0,115	-0,434	0,0738*	0,151	0,277	0,297	0,297	1
	p	0,877	0,496	0,213	0,506	0,752	0,211	0,015	0,678	0,439	0,405	0,405	
**.Correlation is significant at p <0.01													
*. Correlation is significant at p <0.05													

Conclusion

It is clear from this study that the pH of the water is around 7.7 ± 0.1 to a mean temperature of 27.8 ± 0.2 ° C. The suspended solids are present in all waters with an average of 0.0355 ± 0.026 mg / L. phosphates and the electrical conductivity are high in 30% of the wells. The other parameters measured (TDS, ammonium and nitrates) are relatively smaller than the values indicative of pollution levels. Search for bacteriological contamination indicators (total coliforms, faecal streptococci, faecal coliform and heterotrophic mesophilic aerobic bacteria) is positive in all wells. Their presence in the water used by people in the consumption cycle is evidence of pollution, particularly from animal pollution faeces of cattle and sheep stay near structures, reconciliation with latrines or any other activity generating wastewater. Therefore, we note a lack of knowledge of hygiene by people in establishment, protection and maintenance of the wells.

References

[1] **Sighomnou D.,**Cameroun : Gestion intégrée des eaux de crues cas de la plaine d'inondation du fleuve Logone,Technical support unit, Pp 1-8,(2003).

[2] **PNDP.,** Plan de Développement Communal de Maroua 3ème 2010-2015,64p, (2010).

[3] **Nkhuwa DCW.,**Human activities and threats of chronics epidemics in a fragilegeologic environment, PhysicsandChemistry of the Earth, pp 1139-1145,(2003).

[4] **Laferriere M, Minville J.J, Lavoie J, Payment P.,**L'industrie porcine et les risques reliés à la santé humaine,Bull. Information Santé Environnement, Québec, pp1-4,(1996).

[5] **WHO.,**Technologie de l'approvisionnement en eau et de l'assainissement dans les pays en développement, Série de rapports techniques 742, Genève, 44p, (2000).

[6] **WHO.** Directives des qualités pour l'eau de boisson (3ème édition), Volume 1, Recommandations, 110p, (2004).

[7] **Angulo F.J, Tippen S, Sharp D.J, Payne B.J, Collier C, Hill J.E, Barrett T.J, Clark R.M, Geldreich E.E, Donnell H.D, SwerdlowD.,** A CommunityWaterborne Outbreak of salmonellosis and the effectiveness of a Boil Water Order, Am J Public Health, pp580–584, (1997).

[8] **Balbus JM, Embrey MA,**Risk factors for waterborne enteric infections, CurrOpinGastroenterol, pp 46–50, (2002).

[9] **Gounot A.M.,**Microbial Ecology of Groundwater.Academic Press Inc, pp 189 - 219,(1994).

[10] **MoussaDjaouda, Nola M., Gake B., EbangMenye D., Njine T.,**Faecal Contamination of Well Water in Garoua (Cameroon): Importance of Household Storage and Sanitary Hygiene, International Journal of Research in Chemistry and Environment, 7p, (2011).

[11] **MoussaDjaouda, Nola M., Gake B., EbangMenye D., Njine.T.,** Bacteriological Quality of Well Waters in Garoua, NorthCameroon, WaterQual Expo Health.18p, (2014).

[12] **RodierJ.,**L'Analyse de l'eau: Eaux Naturelles, eaux Résiduaires, eaux de Mer, Chimie, Physicochimie, Microbiologie, Biologie, Interprétation des Résultats, DUNOD, Paris, 1579p, (2009).

[13] **Close M.E, Hodgson L.R, Todgre G.,** Field evaluation of fluorescent whitening agents and sodium tripolyphosphate as indicator of septic tank contamination in domestic wells, NewZeal.J. MarineFresh.Res, pp 563-568, (1989).

International Journal of Current Trends in Engineering & Technology
Volume : I, Issue : II (Jan.- Feb. 2015)

[14] **WHO,** Guidelines for drinking-water quality, 2e édition; vol 2: Health criteria and other supporting information,104p,(1996).

[15] **MbawalaA. etNgassoum M.B.,** Evaluation de la pollution physico-chimique et microbienne des eaux de puits de Dang-Ngaoundéré (Cameroun). International Journal of Biological and Chemical Sciences, 14 p, (2010).

[16] **MassartD. L., Vandeginste B. G. M., Deming S. N., Michotte Y., & Kaufman L.,**Principal components and factor analysis.Chemometrics: A textbook. Amsterdam: Elsevier,pp. 339–369,(1988).

[17] **Geldreich E.E.,** Klebsiella.Dans:American Water Works Association manual of water supply practices,Pp 596-602,(1999).

[18] **Robertson W.** Utilités et limites des indicateurs microbiologiques de la qualité de l'eau potable, Dans : Air intérieur et eau potable, sous la direction de Pierre Lajoie et Patrick Levallois, Presses de l'Université Laval, Pp 179-193,(1995).

[19] **CEAEQ.,**Recherche et dénombrement des bactéries hétérotrophes aérobies et anaérobies facultatives, méthode par incorporation à la gélose, centre d'expertise en analyse environnementale du Québec, Gouvernement du Québec, 24 P, (2000).

[20] **Rusin P.A, RoseJ.B, HaasC.N et Gerba.C.P.,**Risk assessment of opportunistic bacterial pathogens in drinking water, Rev Environ ContamToxicol, Pp 57-83, (1997).

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